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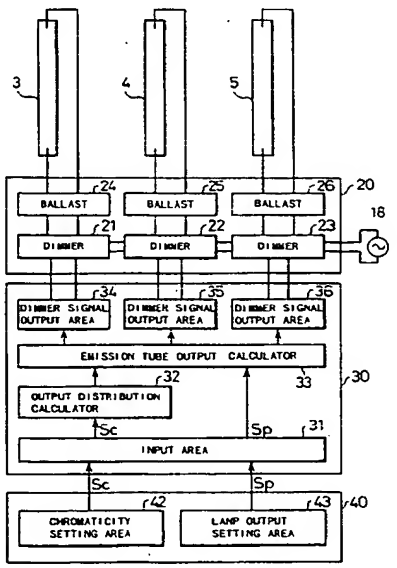
(54) VARIABLE COLOR LAMP.

(57) A variable color lamp of which the chromaticity of the light can be varied. The variable color lamp (1) has first, second, and third arc tubes (3, 4 and 5), each being a metal halide tube, in an outer tube (2). Main electrodes enclosed in the respective arc tubes are connected with a power controlling circuit (20). The first arc tube (3) in which indium halide is sealed emits light of a strong line spectrum in bluish violet. The second arc tube (4) in which thallium halide is enclosed has a strong line spectrum in green. The third arc tube (5) in which sodium halide is enclosed has a strong line spectrum in yellowish red. The color of light of the lamp can be adjusted to any color in the almost whole range of visible rays on x-y chromaticity diagram by changing the relative intensities of light of the respective arc tubes through the use of the power controlling circuit, etc.

Fig. 3



EP 0 494 310 A1

Technical Field

The present invention relates to a variable color lamp with a dimmer function.

Background Art

When a light source includes a number of lamps with different luminous colors, the color of the light emitted from the source is varied by switching over the lamps.

Several devices have been proposed for continuously changing the chromaticity of light emitted from a discharge lamp; for example, Japanese Patent Publication Gazette No. Sho-53-42386 and Japanese Patent Laying-Open Gazette No. Sho-63-198295. In such devices, gas or vapor sealed in a discharge lamp as a luminescent material varies its luminous color corresponding to the intensity of electronic energy, that is, the waveform of a pulse, in the discharge lamp. When the ratio of power supplying time to idle period is relatively large, the color of the light emitted from the lamp is blue; on the other hand, when the ratio is relatively small, the color of the light emitted from the lamp is red.

The former method, however, requires a large number of luminous lamps corresponding to various colors and therefore makes a device bulky. Such a device occupies large space and is not suitable for private purposes, that is, lighting in or out of the houses or illumination at shop windows.

In the latter method, on the other hand, since a longer idle period is required for red light emission, power supplied to the discharge lamp becomes rather small and luminance of the light may be insufficient for illumination.

The objective of the invention is thus to provide a space-saving variable color lamp which emits light of various chromaticity and sufficient luminance.

Disclosure Invention

The invention attains the foregoing and other objectives with a variable color lamp with a dimmer function, which includes: plural emission tubes each emitting light of different chromaticity; and control means for regulating power supplied to each of the plural emission tubes.

Power supplied to each of the emission tubes is regulated by the control means, and each emission tube emits light of self-luminous color corresponding to the power.

The variable color lamp of the invention occupies smaller space than the conventional light source including a large number of lamps with different luminous colors. The color lamp of the invention does not require idle period for light emission of any color or tint and can thus emit light of neutral tints with sufficient luminance.

The simple structure of the invention attains light emission of a wide range of color variation at relatively low cost.

The control means includes a relative output control unit for varying the relative output or the quantity of light emitted from each of the plural emission tubes. The variable color lamp of the invention thus emits light of a neutral tint according to the relative outputs of the plural emission tubes. Namely, the luminous color of the lamp is varied corresponding to color matching functions of chromaticity coordinates.

In another aspect, the invention comprises a variable color lamp including: a first emission tube for emitting blue light of a first wavelength range; a second emission tube for emitting green light of a second wavelength range; and a third emission tube for emitting red light of a third wavelength range.

The color lamp of the invention has the three emission tubes each discharging light of one of the additive primaries proper to the tube, thus attaining a wider color variation and reproducing the color of irradiated objects vividly.

The first through the third emission tubes are all discharge tubes; the first emission tube includes indium halide sealed therein; the second emission tube includes thallium halide sealed therein; and the third emission tube includes sodium halide sealed therein.

In the variable color lamp including the first through the third emission tubes each emitting light of one of additive primaries proper to the tube or discharging color light determined by the metal halide sealed in the tube, the first through the third emission tubes are arranged adjacent to and parallel to one another.

The three emission tubes may be arranged in parallel on the same plane such that the first emission tube is placed in between the second and the third emission tubes. The emission tube disposed in the middle is the first emission tube with indium halide sealed therein which has a narrow dimmer range than thallium halide or sodium halide.

The three emission tubes disposed adjacent to and parallel to one another or arranged in parallel on the same plane in the predetermined order may be integrally formed in the variable color lamp of the invention. Such structure enables the adjacent emission tubes to transfer thermal energy generated from the tubes to each other and to attain uniform temperature rise. Each emission tube thus reaches stable lighting conditions within a short time period.

The emission tube disposed in the middle receives thermal energy generated from both the

side tubes. Namely, the middle tube with indium halide receives thermal energy from both the adjacent emission tubes and is thereby maintained at high temperature.

This structure of the invention attains a wider range of color variation of the emission tubes as described below.

A high intensity discharge lamp including one emission tube generally has a dimmer range of approximately ten percent. The dimmer range of the discharge lamp is narrower than incandescent lamps and tungsten halogen lamps because of the following reasons. In the high intensity discharge lamp, when input to the emission tube is limited in order to decrease the light flux, the temperature in the emission tube is lowered and the luminescent material such as In (indium), Tl (thallium), or Na (sodium) sealed in the emission tube varies its partial vapor pressure. When the partial vapor pressure drops down to a predetermined threshold or lower value, the lamp does not discharge any light but is in 'OFF' state. In the conventional high intensity discharge lamp with only one emission tube, the possible dimmer range is within approximately ninety percent of the rated output.

In the variable color lamp of the invention, on the other hand, plural emission tubes are disposed adjacent to and parallel to each other, and thermal energy generated from each emission tube is transferred to the other emission tubes through the common side wall of the tubes. Even when input to one emission tube is limited, thermal energy generated from the adjacent emission tubes is given to that one tube. Accordingly the emission tube with limited input in the structure of the invention is maintained at higher temperature than the only one emission tube with limited input in the conventional high intensity discharge lamp. The partial vapor pressure of the luminescent material sealed in the emission tube with limited input does not vary but is kept relatively constant, so that the possible dimmer range of the emission tube becomes wider.

Input to one emission tube may be decreased while input to the other two emission tubes is increased. This allows the total input to the whole variable color lamp to be kept constant and thereby prevents the temperature fall of the emission tube with limited lower input so as to attain a wider dimmer range.

The variable color lamp of the invention can emit light of a wider chromaticity range corresponding to the wider dimmer range of the emission tube.

In the variable color lamp of the invention, the emission tube disposed in the middle contains indium halide emitting bluish purple line spectrum and having a relatively narrow dimmer range. Thallium halide emitting green line spectrum and having a relatively wide dimmer range and sodium halide emitting reddish orange line spectrum and having a relatively wide dimmer range are respectively sealed in the side emission tubes arranged in parallel with the middle tube.

When input to the middle emission tube with indium halide having a relatively narrow dimmer range is decreased and the same to the side emission tubes with thallium halide or sodium halide having a relatively wide dimmer range is increased, thermal energy generated from the side tubes is transferred to the middle emission tube so as to maintain the middle tube at high temperature. The possible dimmer range of the middle emission tube is thus made wider than the original dimmer range of the sealed luminescent material.

The plural emission tubes of the invention are composed of translucent alumina ceramics prepared by sintering fine powdery alumina of at least 99.99 mol% in purity. The average grain diameter of the translucent alumina particles is not greater than one micrometer and the maximum grain diameter is not greater than two micrometer.

Since high purity of alumina does not virtually form the grain boundary phase, the emission tube of translucent alumina ceramics has improved mechanical strength (bending strength and Weibull coefficient) at ambient to discharge temperatures, compared with an emission tube of conventional translucent ceramics prepared by sintering and growing grains with a sintering accelerator such as MgO. The improved mechanical strength allows the emission tube to have thinner wall and thereby smaller thermal capacity. Accordingly the luminous part of the emission tube is heated to a predetermined temperature at a high speed and warm-up time of the tube is shortened. Here the warm-up time represents a time period until discharging metal component (metal halide) sealed in the tube vaporizes to saturated vapor pressure.

The emission tube may be any discharge tube with high lamp efficacy; for example, metal halide tubes, high-pressure sodium tubes, and fluorescent tubes.

Japanese Industrial Standard JIS Z8110 defines the relationship between the self-luminous color of a monochromatic light source and the wavelength range as follows:

380 to 455 nm: bluish purple
455 to 485 nm: blue
485 to 495 nm: blue green
495 to 548 nm: green
548 to 573 nm: yellow green
573 to 584 nm: yellow
584 to 610 nm: reddish orange
610 to 780 nm: red

In the invention, the wavelength range of blue light denotes 380 to 495 nm; the wavelength range

of green light represents 485 to 573 nm; and the wavelength range of red light is 573 to 780 nm.

Brief Description Of Drawings

Fig. 1 is a vertical cross sectional view showing a variable color lamp of a first embodiment according to the invention;
Fig. 2 is an x-y chromaticity diagram showing the relationship between the relative output of an emission tube and the luminous color in the variable color lamp of the first embodiment;
Fig. 3 is a block diagram showing the electric structure of the variable color lamp of the first embodiment;
Fig. 4 is a perspective view illustrating an emission tube 1M built in a variable color lamp according to a second embodiment;
Fig. 5 is a process chart showing manufacturing process of the emission tube 1M;
Fig. 6 is a perspective view illustrating another emission tube 1N;
Fig. 7 is a graph showing distribution of the grain diameter of translucent alumina constituting the emission tube 1M;
Fig. 8 is a perspective view illustrating another emission tube 1L applied to modification of the second embodiment;
Fig. 9 is a perspective view illustrating another emission tube 1R applied to modification of the second embodiment and a mold used for manufacturing the tube 1R;
Fig. 10 is a perspective view illustrating another emission tube 1S applied to modification of the second embodiment;
Fig. 11(a) is a perspective view illustrating another emission tube 1A used in place of the emission tubes 1R and 1S;
Fig. 11(b) is a Y-plane cross sectional view of Fig. 11(a);
Fig. 12 is a process chart showing manufacturing process of the emission tube 1A;
Figs. 13(a) and 13(b) are perspective views showing a mold used in manufacture of the emission tube 1A;
Fig. 14 is an explanatory view illustrating manufacture of the emission tube 1A; and
Fig. 15 is an explanatory view also illustrating manufacture of the emission tube 1A.

Best Mode for Carrying Out the Invention

Preferred embodiments of the invention are hereinafter described in detail according to the drawings.

Fig. 1 is a vertical cross sectional view showing a variable color lamp of a first embodiment according to the invention.

A variable color lamp 1 includes a first emission tube 3, a second emission tube 4, and a third emission tube 5 via a support 15 in an outer bulb 2 having a reflector mirror 17 on the upper side thereof. The outer bulb 2 is composed of a translucent material having light scattering ability, for example, frosted glass, milky glass or acrylic resin. Metal halide (luminescent material) for emitting light of a different luminous color is sealed with mercury and starting noble gas in each of the emission tubes 3 through 5. A pair of primary electrodes 6 and 9, 7 and 10, or 8 and 11 are adhered to either end of the emission tube via molybdenum foils. Auxiliary starting electrodes 12, 13, and 14 are also fixed to the lower end of the emission tubes, respectively. The primary electrodes and the auxiliary starting electrodes are connected to a power control circuit 20 (described later) through pins 16.

The emission tubes 3 through 5 are composed of quartz glass, and the primary electrodes mounted on both the ends of the emission tube are coils of tungsten and the like. The outer bulb 2 may be evacuated or filled with gas.

The first emission tube 3 contains indium halide such as InI_3 with mercury and starting noble gas, and emits bluish purple line spectrum at the wavelength around 411 nm or 451 nm. The second emission tube 4 contains thallium halide such as TlI with mercury and starting noble gas, and emits green line spectrum at the wavelength around 535 nm. The third emission tube 5 contains sodium halide such as NaI with mercury and starting noble gas, and emits reddish orange line spectrum at the wavelength around 589 nm.

Fig. 2 is an x-y chromaticity diagram showing the relationship between the relative output of the emission tube and the luminous color. In the diagram, points A, B, and C represent luminous colors of the emission tubes 3 through 5, respectively. The luminous color of the variable color lamp 1 may be varied within a triangle of the three points A, B, and C in conformity with the rule of color addition (the additive mixture of colors). For example, when outputs of the second and the third emission tubes 4 and 5 are set greater than that of the first emission tube 3, the luminous color of light emitted from the variable color lamp 1 is pale yellowish green shown by a point D.

The electric structure of the variable color lamp 1 of the first embodiment is explained based on the block diagram of Fig. 3. The auxiliary starting electrodes are omitted in the diagram since they are not essential for the scope of the invention.

The power control circuit 20 includes three dimmers 21, 22, and 23 and three ballasts 24, 25, and 26 corresponding to the three emission tubes 3, 4, and 5. The dimmers 21 through 23 are semi-

conductor phase control circuits connected to an AC power source 18 in series. When the emission tubes 3 through 5 have different rated voltages, each dimmer may be connected to an individual AC power source for applying a different rated voltage.

A color control circuit 30 includes an input area 31, an output distribution calculator 32, an emission tube output calculator 33, and three dimmer signal output areas 34, 35, and 36.

A remote control unit 40 includes a chromaticity setting area 42 and a lamp output setting area 43. The remote control unit 40 has a series of keys for inputting commands and a display for showing operation of the lamp.

The luminous color or the light flux of the lamp may be varied by setting the chromaticity and output of the lamp through the keys of the remote control unit 40. The chromaticity is, for example, input as coordinate values on the x-y chromaticity coordinates. The coordinates of the point D in Fig. 2 are (0.37, 0.45) in the x-y chromaticity coordinate system. The output of the lamp is, for example, input as a percentage relative to the maximum output of the lamp at each chromaticity. The chromaticity setting area 42 and the lamp output setting area 43 of the remote control unit 40 respectively generate a chromaticity signal Sc and a lamp output signal Sp corresponding to the input values, and transfer data to the input area 31 of the color control circuit 30.

The chromaticity signal Sc is sent from the input area 31 to the output distribution calculator 32, which determines the relative value of the total luminous flux emitted from each of the three emission tubes 3 through 5 according to the additive mixture of colors so as to attain the chromaticity shown by the chromaticity signal Sc.

The emission tube output calculator 33 determines the output level of each emission tube based on the relative value of the total luminous flux, that is, the relative output, of the emission tube determined by the output distribution calculator 32 and the lamp output signal Sp. The output level of the emission tube having the maximal relative output determined by the output distribution calculator 32 is set equal to a value multiplying the rated output of the emission tube by the relative output (percent) shown by the lamp output signal Sp. For example, when the relative output values of the three emission tubes are 0.6: 0.4: 1.0 and the relative output of the lamp output signal Sp is seventy percent, the output levels of the emission tubes are respectively set to 42%, 28%, and 70%.

Signals representing the output levels of the emission tubes are sent from the emission tube output calculator 33 to the three dimmer signal output areas 34 through 36, which generate dimmer signals (fade signals) for controlling the dimmers 21 through 23. Each of the dimmers 21 through 23 controls a continuity phase angle of current supplied to the emission tube corresponding to the dimmer signal output from the dimmer signal output area 34, 35, or 36. Current running through the emission tube and the total luminous flux of the emission tube are thus adjusted. Since the efficiency of the emission tube varies with the current, the total luminous flux is not always proportional to the feed quantity. The emission tube output calculator 33 corrects the signals, which are sent to the dimmer signal output areas 34 through 36, with a predetermined calibration curve according to the relationship between the total luminous flux of the emission tube and the feed quantity, such that the ratio of the output signals is equal to the ratio of the total luminous fluxes of the emission tubes determined by the output distribution calculator 32.

The emission tubes 3 through 5 are installed in the outer bulb 2 composed of a translucent material with light scattering function, for example, frosted glass, milky glass or acrylic resin. Mixing failure of the luminous fluxes of the plural colors due to misalignment of the emission tubes is hence well prevented by the blurring of such a translucent material.

The variable color lamp 1 of the first embodiment includes three emission tubes each discharging color light similar to one of additive primaries, that is, Red, Green, and Blue. The luminous color of the variable color lamp 1 is adjustable within almost the whole visible light on the x-y chromaticity diagram by varying the relative outputs of the emission tubes. Namely, the luminous color of the lamp is varied corresponding to color matching functions of the chromaticity coordinate system. The line spectra of the emission tubes are also close to the additive primaries , and the color of an irradiated object is thereby reproduced vividly.

The emission tubes 3 through 5 of the variable color lamp 1 may be any discharge tube such as incandescent tubes, fluorescent tubes, high-pressure sodium tubes, and neon tubes as well as the metal halide tubes used in the first embodiment. For example, when a neon tube emitting red line spectrum is used for the third emission tube 5 (the metal halide tube containing sodium halide such as NaI in the first embodiment), wider color variation is implemented.

Emission tubes emitting continuous spectrum may be used in place of those with line spectrum in a certain wavelength range.

In another aspect, certain additives may be mixed with alumina to give specific spectral characteristics to the translucent alumina emission tube with hydrogen, iodine, and starting noble gas seal-

ed therein. When chromium compound is added to alumina, red line spectrum is obtained; cobalt compound for blue line spectrum; and nickel or zinc compound for green line spectrum. The specific spectral characteristics may be attained by coloring the whole emission tube or forming a colored layer on the surface of the emission tube. In the first method, solid solution of the metal oxide (additive) is mixed with alumina while translucent alumina is sintered. In the latter method, on the other hand, solid solution of the metal oxide is painted on the circumference of the alumina emission tube.

The number of the emission tubes is determined according to the requirement. Two emission tubes are, for example, used when the coloring range is a line, while four tubes are used when a wider band range should be covered.

Another variable color lamp of a second embodiment according to the invention is described hereinafter. In the following description, members having the same functions as the first embodiment may not be explained, nor may symbols or numerals assigned to such members be omitted.

In the first embodiment, the three emission tubes 3 through 5 are independently installed in the outer bulb. The second embodiment, on the other hand, includes an emission tube 1M consisting of three emission pipes integrally formed in parallel on the same plane as shown in Fig. 4.

The emission tube 1M, composed of translucent alumina, is a multi-pipe tube consisting of three single emission pipes 1m1, 1m2, and 1m3 which are integrally formed adjacent to and parallel to one another. Each emission pipe has a pair of primary electrodes and generates linear electric discharge space. The side wall of the single emission pipes 1m1 and 1m2 or 1m2 and 1m3 is in common as indicated by shaded parts in Fig. 4.

The inner diameter of each single emission pipe 1m1, 1m2, and 1m3 ('d' in Fig. 4) is approximately 4.0 mm, and the wall thickness ('d0' in Fig. 4) is about 0.2 mm. The distance between the primary electrodes adhered in each emission pipe is approximately 30 mm.

Manufacture of the emission tube 1M is described according to the process chart of Fig. 5.

Fine powdery alumina, material of the emission tube 1M is first synthesized. Aluminum salt, which gives at least 99.99 mol% in purity of alumina by pyrolysis, is used as a starting material. Examples of such aluminum salt for yielding high purity of alumina include ammonium alum and aluminum ammonium carbonate hydroxide ($NH_4AlCO_3(OH)_2$).

The aluminum salt is weighed, mixed with distilled water and a dispersing agent to a suspension, and dried by spray drying. The dried salt is then pyrolyzed to fine powdery alumina at the temperature between 900 and 1200 °C, for example, 1050 °C, in the atmosphere for two hours. Through the process of spray drying and pyrolysis, fine powdery alumina (average grain diameter: 0.2 to 0.3 micrometer, purity: at least 99.99 mol%) is prepared. Secondary aggregate of alumina fine powder, which has a greater diameter than the powder, is actually yielded.

An organic binder mainly consisting of acrylic thermoplastic resin is mixed with the secondary aggregate of alumina fine powder. The mixture in an organic solvent such as benzene is wet stirred with a plastic or nylon ball mill for approximately twenty-four hours, so that the organic binder and alumina fine powder are sufficiently wet. The mixture is then evaporated for removal of the solvent and kneaded to yield a compound of a desired viscosity (50,000 to 150,000 cps) (process 1).

The organic binder consists of acrylic thermoplastic resin, paraffin wax, and atactic polypropylene, and the total quantity of the binder is 25 g with respect to 100 g of alumina fine powder.

The content of each component of the organic binder is as follows:

Acrylic thermoplastic resin: 20 to 23 g
(preferably 21.5 g)
Paraffin wax: not greater than 3 g
(preferably 2.0 g)
Atactic polypropylene: not greater than 2 g
(preferably 1.5 g)
Here, the total of the contents should be 25 g.

The mixture is evaporated at 130 °C for twenty four hours and kneaded at 130 °C with an alumina roll mill to yield a compound.

The compound is injected into a cavity of a mold on an injection molding device (not shown) and molded to a multi-pipe body W0, shown in Fig. 4, consisting of three cylindrical emission pipes integrally formed adjacent to and parallel to one another (process 2). The compound is previously heated to 130 to 200 °C (preferably 180 °C), and then injected from a nozzle of an injection device under the pressure of 900 to 1,800 kg/cm^2.

The compound is solidified in the injection cavity to the molded body W0 under the certain pressing conditions; the pressure of 180 to 800 kg/cm^2 is kept for 0.5 to 5 seconds. The molded body W0 thus obtained has 0.99 or higher transferability (dimensions of the molded body / those of the mold), 0.99 or higher circularity, and 0.99 or higher contraction ratio (in the direction of the diameter / that of the axis). The inner diameter of each cylindrical pipe of the molded body W0 is determined to be approximately 4.85 mm by considering volume shrinkage on sintering. The wall thickness ('d0' in Fig. 4) of each cylindrical pipe is set to be approximately 0.3 mm by considering volume shrinkage on sintering and grinding margin.

After completion of the injection molding pro-

cess (process 2), the molded body W0 is parted from the mold on the injection molding device (process 3).

The molded body W0 is heated in nitrogen atmosphere to a temperature at which the organic binder containing acrylic thermoplastic resin is pyrolyzed and completely carbonated. Namely, the molded body W0 is degreased (process 4). The upper limit of the heating temperature in this initial heat treatment is determined according to the performance of the heat treatment furnace and the pyrolytic temperature of the organic binder. In this embodiment, the molded body W0 is heated from the room temperature (20 ° C) to 450 ° C for seventy-two hours. The conditions of the initial heat treatment are as follows:

Pressure: 1 to 8 kg/cm^2

(optimal pressure is 8 kg/cm^2)

Time period for heating from 20 ° C to 450 ° C: not longer than seventy-two hours.

Here, the pressure is kept constant during heating up to 450 ° C.

The organic binder of acrylic thermoplastic resin, paraffin wax, and atactic polypropylene mixed in the compound is pyrolyzed and carbonated through this initial heat treatment, so that the molded body W0 is sufficiently degreased.

The degreased body W0 is again applied to heat treatment in the atmosphere so as to be sintered (process 5). The conditions of the secondary heat treatment are given below; here the heating rate is 100 ° C / hour:

Temperature: 1,200 to 1,300 ° C

(optimum temperature: 1,235 ° C)

Time period of treatment at the above temperature: zero to four hours (optimum time period: two hours)

The sintering temperature is set in the range of 1,200 to 1,300 ° C so as to make the actual density of the sintered body not less than 95% of the theoretical density for the following hot isostatic pressing and prevent growth of undesirable rough crystals. When the temperature is 1,200 ° C or lower, the density of the sintered body drops to the level unsuitable for hot isostatic pressing, that is, less than 95% of the theoretical density. When the temperature is, on the other hand, over 1,300 ° C, formation of rough crystals decreases the strength of the sintered body.

Through the initial and secondary heat treatment for degreasing and sintering, the volume of the molded body is shrunk to 82.5%, and the packing factor of the sintered body becomes approximately 100% (bulk density: 3.976). Carbides produced in the process of the initial heat treatment are completely burned out and removed from the sintered body through the sintering process.

The sintered body is exposed to hot isostatic pressing in argon atmosphere or the atmosphere of argon with oxygen of not greater than 20vol% (process 6). The conditions of the hot isostatic pressing are given below; here the heating rate is 200 ° C / hour:

Temperature: 1,200 to 1,250 ° C

(optimum temperature: 1,230 ° C)

Pressure: 1,000 to 2,000 atm

(optimum pressure: 1,000 atm)

Time: one to four hours (optimum time: two hours)

The sintered body acquires translucency through this process, and the multi-pipe emission tube 1M of translucent alumina is thus obtained.

The temperature and pressure ranges for hot isostatic pressing are determined so as to give desirable translucency to the sintered body and improve the mechanical strength thereof. When the hot isostatic pressing is implemented at the temperature lower than 1,200 ° C or under the pressure lower than 1,000 atm, sufficient translucency is not given to the sintered body. When the temperature is over 1,250 ° C, on the other hand, abnormal grain growth lowers both translucency and mechanical strength. When the pressure is over 2,000 atm, even very small pores or scratches in the sintered body may cause fatal cracks due to stress concentration.

Both ends of the multi-pipe emission tube 1M of translucent alumina are then ground with a diamond grinding wheel, and the inner and outer surface of the emission tube 1M is ground and polished to have the wall thickness not greater than 0.2 mm by using a brush with diamond abrasive grains (grain diameter: 0.5 micrometer) (process 7). This grinding process smooths the surface of the emission tube to prevent scattering of light on the surface, thus improving the linear transmittance.

Through the process 1 to 7, obtained is the emission tube 1M shown in Fig. 4, consisting of three single emission pipes 1m1, 1m2, and 1m3, which are integrally formed adjacent to and parallel to one another and have the common side wall shown by the shaded parts in the drawing. The emission tube 1M thus prepared has the inner diameter of about 4.0 mm (wall thickness: approximately 0.2 mm) and the total length of approximately 40 mm.

The emission tube 1M with pairs of primary electrodes is, in use, installed in the outer bulb of the variable color lamp. Luminescent materials are individually sealed in each of the single emission pipes 1m1, 1m2, and 1m3 of the emission tube 1M. Examples of such luminescent materials include: indium halide emitting bluish purple line spectrum, thallium halide emitting green line spectrum, and sodium halide emitting reddish orange line spectrum. In one embodiment, indium halide is sealed in the single emission pipe 1m1; thallium

halide in the single emission pipe 1m2; and sodium halide in the single emission pipe 1m3.

The variable color lamp of the second embodiment has the multi-pipe emission tube 1M consisting of the three single emission pipes 1m1, 1m2, and 1m3 integrally formed adjacent to and parallel to one another, while the first embodiment has three independent emission tubes 3 through 5 installed in the outer bulb. The second embodiment has the following effects as well as those of the first embodiment including variation of the luminous color corresponding to the color matching functions of the chromaticity coordinate system.

In the integral emission tube 1M of the variable color lamp, the side wall of the adjacent single emission pipes 1m1 and 1m2 or 1m2 and 1m3 is formed in common. Thermal energy is freely transferred between the adjacent single emission pipes through the common side wall, thus allowing the wall temperature of the single emission pipes 1m1, 1m2, and 1m3 to rise uniformly. The whole emission tube 1M is accordingly stabilized within a short time period, and the warm-up time is favorably shortened.

When plural emission tubes are arranged not in contact with or adjacent to one another in the lamp, arc discharge between the pair of primary electrodes starts at a different moment in each emission tube, and heat generation due to arc discharge is made different among the tubes. The plural emission tubes differ in the heating time period for raising the wall temperature of the emission tube to a predetermined value (the temperature at which sealed discharge material is evaporated in the emission tube to give saturated vapor pressure). Accordingly the plural emission tubes are not stabilized at the same time or on the whole within a short time.

On the contrary, in the structure of the multi-pipe emission tube 1M, the temperature of the single emission pipes increase uniformly to a predetermined value based on heat transfer through the common wall. The plural emission pipes or the whole emission tube 1M is thus stabilized almost simultaneously and the warm-up time of the variable color lamp is significantly shortened.

Heat transfer between the adjacent single emission pipes 1m1 and 1m2 or 1m2 and 1m3 of the emission tube 1M expands the possible dimmer range of each single emission pipe.

A high intensity discharge lamp including an emission tube generally has a dimmer range of approximately ten percent. The dimmer range of the discharge lamp is significantly narrower than incandescent lamps and tungsten halogen lamps because of the following reasons. In the high intensity discharge lamp, when input to the emission tube is limited in order to decrease the light flux, the temperature in the emission tube is lowered and the luminescent material such as In, Tl, or Na sealed in the emission tube varies its partial vapor pressure. When the partial vapor pressure drops down to a predetermined threshold or lower value, the lamp does not discharge any light but is in 'OFF' state. In the conventional high intensity discharge lamp with only one emission tube, the possible dimmer range is within approximately ninety percent of the rated output. In the variable color lamp 1 of the first embodiment including independent three emission tubes, the possible dimmer range is also about ninety percent.

In the emission tube 1M of the second embodiment, on the other hand, since three single emission pipes are arranged adjacent to and parallel to one another and have the common side wall, thermal energy generated from each emission pipe is transferred to the other emission pipes through the side wall. Even when input to one emission pipe is limited, thermal energy generated from the adjacent emission pipes is given to that one pipe. Accordingly the single emission pipe with limited input in the emission tube 1M of the variable color lamp is maintained at higher temperature than the only one emission tube with limited input in the conventional high intensity discharge lamp. The partial vapor pressure of the luminescent material sealed in the single emission pipe with limited input does not vary but is kept relatively constant, so that the possible dimmer range of the variable color lamp becomes wider.

Input to one emission pipe may be decreased while input to the other two emission pipes is increased. This allows the total input to the whole emission tube to be kept constant and thereby prevents the temperature fall of the single emission pipe with limited lower input so as to attain a wider dimmer range.

The variable color lamp with the emission tube 1M has wider variation of chromaticity of the emitted light corresponding to the wider dimmer range of the emission tube.

Arrangement of the single emission pipes with metal halides sealed therein attains the following effects besides the wider dimmer range.

In the emission tube 1M of the embodiment, the single emission pipe 1m2 disposed in the middle contains indium halide emitting bluish purple line spectrum and having a narrower dimmer range than thallium and sodium. Thallium halide emitting green line spectrum is in the single emission pipe 1m1, and sodium halide emitting reddish orange line spectrum in the single emission pipe 1m3. When input to the middle emission pipe 1m2 with indium halide having a relatively narrow dimmer range is decreased and the same to the adjacent emission pipes 1m1 and 1m3 is increased, thermal

energy generated from the adjacent emission pipes 1m1 and 1m3 is transferred to the middle emission pipe 1m2 so as to maintain the middle emission pipe at high temperature. The possible dimmer range of the middle emission pipe 1m2 is thus made wider than the original dimmer range of indium. Another emission tube 1N shown in Fig. 6 may be used for the emission tube 1M to give the similar effects.

The properties of the emission tube 1M are given below:

Linear transmittance to visible light (wavelength: 380 to 760 nm): not less than 70%

Linear transmittance to light having the wavelength of 500 nm: 82% (wall thickness: 0.5 mm)

Average grain diameter: approximately 0.7 micrometer

(maximum grain diameter: 1.4 micrometer)

Mechanical strength (JIS R1601)

Bending strength St: (room temperature) = 98 kg/cm^2

(900 °C) = 81 kg/cm^2

Weibull coefficient: (room temperature) = 9.3

(900 °C) = 8.1

Above data including the grain diameter and the mechanical strength was determined not for the emission tube 1M itself of the embodiment but for a sample prepared under the various conditions specified in the above manufacturing process (the shape and the thickness of the sample were in conformity with JIS R1601).

The grain diameter was determined in the following manner. The surface of the sample prepared to have the shape and thickness in accordance with JIS R1601 was lapped with diamond abrasive grains and exposed to molten potassium hydroxide for intergranular etching. The image of the grain was analyzed based on observation of the surface of the sample with a scanning electron microscope. For the image analysis, the grain was assumed to be spherical or polygonal, and the maximum value of the diameter or the distance between vertexes was used for calculation of the grain diameter. Fig. 7 shows a distribution diagram of the grain diameter determined by assuming the spherical grain.

The sample was cut to have the thickness of 0.5 mm and finished by lapping the surface, and the linear transmittance was measured with a double beam spectrophotometer.

Observation of the tissue with a transmission electron microscope (TEM) did not show any grain boundary phase, undesirable pore in the grain, nor lattice defect, which may cause scattering of light.

The emission tube 1M is composed not of the conventional translucent alumina, which is sintered with a sintering accelerator such as MgO to make large rough grains, but of fine powdery alumina. The excellent translucency of the alumina of the embodiment may be ascribed to the following reasons.

Since alumina (before sintering) contains only a very little amount of impurity (maximum: 0.01 mol%), all the impurity is molten in the alumina and does not substantially form any grain boundary phase such as a spinel phase. Effects of the grain boundary phase, which causes scattering of light, are thus eliminated, and the linear transmittance to the visible light is sufficiently improved.

Another possible reason is further given below.

When both the cross sections of the grain and the grain element are assumed to be circular, the following equation (1) is held. Here, the grain of the diameter D consists of n grain elements of the diameter d.

$$(1) \quad n = (D/d)^2$$

The value of n determined by the equation (1) represents the number of the interface between grain elements contained in the cross section of a grain.

The lattice constant was determined with an X-ray diffractometer for various translucent alumina grains (average grain diameter: 0.72, 0.85, 0.99, 1.16, 1.35, and 1.52 micrometer) of highly pure alumina. The diameter d of the translucent alumina grain element was then determined for the various translucent alumina grains above by substituting the value of the (012) diffraction peak in Scherrer's expression which defines the relationship between the diameter d of the grain element and the width of the diffraction line. The results show that the diameter d of the grain element is constant irrespective of the size of the grain. The Scherrer's expression is shown in 'P. Gallezot, Catalysis, Science, and Technology; vol. 5; p221, Springer-Verlag (1984)' or 'P. Scherrer; Gottinger Nachrichen; 2; 98, (1918)'.

The above equation (1) accordingly proves that the smaller average diameter D of the grain implies the smaller number of the interface between grain elements in one grain.

When light enters polycrystal such as ceramics, it is scattered on the face with the discontinuous refractive index or discontinuous atomic arrangement. The interface between the grain elements in the grain has discontinuous atomic arrangement and thus causes scattering of light. The smaller number of the interface between the grain elements in the grain, that is, the smaller diameter D of the grain eliminates undesirable effects of the interface, which cause scattering of light, and improves the linear transmittance to the visible light.

Some modification of the above embodiment is described hereinafter.

The three emission pipes are arranged in parallel on the same plane in the second embodiment. Three single emission pipes may, however, be disposed in contact with and parallel to one another to have the common side wall as shown in Fig. 8. In this structure, an emission tube 1L consists of the three emission pipes integrally formed with the excessive wall around the pipes. Indium halide, thallium halide, and sodium halide are separately sealed in the emission pipes of the emission tube 1L in the same manner as the second embodiment.

A variable color lamp with the emission tube 1L has the following effects as well as expansion of the possible dimmer range and the shortened warm-up time described in the second embodiment. The circumference of the emission tube 1L does not have any convex or concave but is smooth, and the cross section of the whole emission tube is a round triangle. The smooth surface efficiently prevents concentration of the thermal stress generated on sintering or switching, which may cause early rupture of the lamp, and the life of the variable color lamp is elongated.

Although each emission pipe of the emission tube is linearly formed in the second embodiment and the above modification, a U-shaped emission pipe may be used instead. An emission tube 1R or 1S which consists of three U-shaped emission pipes integrally formed adjacent to and parallel to one another as shown in Figs. 9 and 10 may, for example, be installed in the outer bulb of the lamp.

A variable color lamp with the emission tube 1R or 1S has the following effects as well as expansion of the possible dimmer range and the shortened warm-up time described in the second embodiment. The center of emission having the maximum luminous flux is located on a curved portion in the emission tube 1R or 1S. When such an emission tube is installed in the outer bulb, the emission center faces the end of the lamp. The variable color lamp can thus be formed relatively small and space-saving in the direction of emission.

Manufacture of the emission tube 1R or 1S is briefly described. The emission tube 1R is prepared with a combination mold shown in Fig. 9, which includes an upper mold 50, a lower mold 51, and a sliding mold 52 slidably disposed between the upper and the lower molds 50 and 51. Each mold has three arc-shaped grooves to form the cavity corresponding to the outer face of the emission tube 1R. Another combination mold with rectangular grooves is used for manufacturing the emission tube 1S having the polygonal or rectangular cross section.

The emission tube 1S or 1R is prepared with such a mold according to the following process. Here manufacture of a single U-shaped emission tube 1A shown in Figs. 11(a) and 11(b) is described based on the process chart of Fig. 12 for clarity and simplicity of the description. Fig. 11(b) is a Y-plane cross sectional view of Fig. 11(a).

High purity (at least 99.99 mol%) of fine powdery alumina (secondary aggregate) prepared by spray drying in the same manner as the second embodiment is mixed with an organic binder such as acrylic emulsion, a deflocculant such as sodium polyacrylate, an antifoamer such as octanol, and distilled water. The mixture is wet stirred with a plastic or nylon ball mill for approximately twenty four hours, so that excessive aggregation of alumina is eliminated and alumina uniformly dispersed in the solvent, that is, slurry, is prepared (process 1).

The contents of the additives with respect to 100 g of fine powdery alumina are as follows:
Organic binder: 3g
Deflocculant: 1g
Antifoamer: 0.1g
Distilled water : 55g

Blow holes are then removed from the slurry (process 2). Slurry taken out of the ball mill is placed in a resin vessel in a vacuum desiccator and stirred with a magnetic stirrer while air in the desiccator is aspirated with a vacuum pump for several minutes (for example, five minutes).

The molded body 1A shown in Figs. 11(a) and 11(b) is prepared with a combination mold 60 shown in Fig. 13(a) through the following process. As described above, the emission tube 1R, which is actually applied to the embodiment, is formed with the combination mold consisting of the upper mold 50, the lower mold 51, and the sliding mold 52.

The combination mold 60 includes symmetrical molds 61a and 61b, which are composed of a porous inorganic material such as plaster or a porous resin containing pores having the similar function to plaster, as shown in Fig. 13(a). A cavity 63 for slurry pour is formed between the joint faces of the molds 61a and 61b.

Each mold 61a or 61b has a U-shaped groove or cavity 63a or 63b on a joint face 65a or 65b thereof as seen in Fig. 13(b). The groove 63a or 63b has a ridge 64a or 64b on the center thereof, which is a little lower than the joint face 65a or 65b. The grooves may previously be molded or cut by using an end mill with spherical teeth on the edge (not shown).

After removal of blow holes from the slurry at process 2, the slurry is poured into the cavity 63 of the combination mold 60 and stood for a predetermined time period (process 3). An excessive amount (more than the volume of the cavity 63) of slurry is poured into a cylindrical body 67 mounted on the upper face of the combination mold 60 as

shown in Fig. 14. The lower face of the cylindrical body 67 and the upper face of the combination mold 60 are sealed with clay or rubber 69.

The solvent (distilled water in the embodiment) contained in the slurry, which is poured into the cavity 63, is absorbed into the pores of the porous molds 61a and 61b while the slurry is stood for the predetermined time period. Alumina grains bound to one another via the organic binder are uniformly aligned along the wall of the cavity 63, and an alumina layer SA is formed as shown in Fig. 15.

The thickness of the alumina layer SA or the inner diameter of the molded body depends on the standing time period. The standing time is thus previously determined through experiments such that the alumina layer SA formed has a desirable inner diameter. The standing time and the dimensions of the groove should be determined by considering the volume shrinkage on sintering. In one embodiment, the standing time is three minutes or shorter to make the inner diameter of the alumina layer SA around 4.82 mm, and the packing ratio approximately 58%. The outer diameter of the alumina layer SA is determined by the dimensions of the cavity 63, and is around 5.54 mm in the embodiment.

The mold may be stood under the negative pressure so that the solvent in the slurry is forcibly aspirated out of the mold. This system attains shorter standing time, direct removal of blow holes from the slurry, and higher packing ratio.

After elapse of the predetermined standing time, slurry remaining in the cylindrical body 67 or on the inner face of the alumina layer SA is removed (process 4). The combination mold 60 is separated into two parts, and the molded body 1A shown in Figs. 11(a) and 11(b) is parted from the mold. The molded body is dried until the solvent is completely eliminated therefrom (process 5).

The molded body is sintered through heat treatment at a predetermined sintering temperature between 1,200 and 1,300 °C, for example, at 1,235 °C for four hours (process 6). Here the heating rate is 100 °C / hour. Through the sintering process, the volume of the molded body is shrunk to approximately 83%, and the packing factor of the sintered body becomes approximately 100% (bulk density: 3.976).

The sintering temperature is set in the range of 1,200 to 1,300 °C so as to make the actual density of the sintered body not less than 95% of the theoretical density for the following hot isostatic pressing and prevent growth of undesirable rough crystals. When the temperature is 1,200 °C or lower, the density of the sintered body drops to the level unsuitable for hot isostatic pressing, that is, less than 95% of the theoretical density. When the temperature is, on the other hand, over 1,300 °C, formation of rough crystals decreases the strength of the sintered body.

The sintered body is exposed to hot isostatic pressing in argon atmosphere or the atmosphere of argon with oxygen of not greater than 20vol% (process 7). The conditions of the hot isostatic pressing are given below; here the heating rate is 200 °C / hour:

Temperature: 1,200 to 1,250 °C
(optimum temperature: 1,230 °C)
Pressure: 1,000 to 2,000 atm
(optimum pressure: 1,000 atm)
Time: one to four hours (optimum time: two hours)

The sintered body acquires translucency through this process, and the emission tube 1A of translucent alumina is thus obtained. The sintered body is embedded in sapphire beads (diameter: 2 mm) or titanium sponge during the hot isostatic pressing.

The temperature and pressure ranges for hot isostatic pressing are determined so as to give desirable translucency to the sintered body and improve the mechanical strength thereof. When the hot isostatic pressing is implemented at the temperature lower than 1,200 °C or under the pressure lower than 1,000 atm, sufficient translucency is not given to the sintered body. When the temperature is over 1,250 °C, on the other hand, abnormal grain growth lowers both translucency and mechanical strength. When the pressure is over 2,000 atm, even very small pores or scratches in the sintered body may cause fatal cracks due to stress concentration.

The emission tube 1A thus prepared has the inner diameter of about 4.0 mm, the wall thickness of approximately 0.3 mm, and the length between the opening and the curve of approximately 20 mm, that is, the total length of approximately 40 mm. Observation of the tissue with a transmission electron microscope (TEM) did not show any grain boundary phase, undesirable pore in the grain, nor lattice defect, which may cause scattering of light.

The inner and outer surface of the emission tube 1A is ground and polished to have the wall thickness not greater than 0.2 mm by using a brush with diamond abrasive grains (grain diameter: 0.5 micrometer) (process 8). This grinding process smooths the surface of the emission tube to prevent scattering of light on the surface, thus improving the linear transmittance. The wall of the tube may be ground to the thickness of 0.05 mm according to the requirements.

The emission tube 1A thus prepared, that is, the emission tube 1R or 1S, has almost the same linear transmittance and average grain diameter as the emission tube 1M of the second embodiment, and possesses the mechanical strength of approximately 80% of the emission tube 1M.

Industrial Applicability

The variable color lamp of the invention described above may be applied to neon signs as well as lighting in or out of the houses or illumination at shop windows.

Claims

1. A variable color lamp with a dimmer function, which comprises:
   plural emission tubes each emitting light of different chromaticity; and
   control means for regulating power supplied to each of the plural emission tubes.

2. A variable color lamp in accordance with claim 1, wherein said control means comprises a relative output control unit for varying the relative output from each of said plural emission tubes.

3. A variable color lamp in accordance with either claim 1 or claim 2, wherein said plural emission tubes comprise: a first emission tube for emitting blue light of a first wavelength range; a second emission tube for emitting green light of a second wavelength range; and a third emission tube for emitting red light of a third wavelength range.

4. A variable color lamp in accordance with claim 3, wherein said first through third emission tubes are all discharge tubes; said first emission tube includes indium halide sealed therein; said second emission tube includes thallium halide sealed therein; and said third emission tube includes sodium halide sealed therein.

5. A variable color lamp in accordance with either claim 3 or claim 4, wherein said first through third emission tubes are arranged adjacent to and parallel to one another.

6. A variable color lamp in accordance with claim 5, wherein said first through third emission tubes are arranged in parallel on the same plane such that the first emission tube is placed in between the second and the third emission tubes.

7. A variable color lamp in accordance with either claim 5 or claim 6, wherein said plural emission tubes are integrally formed.

8. A variable color lamp in accordance with claim 7, wherein said plural emission tubes are composed of translucent alumina ceramics prepared by sintering fine powdery alumina of at least 99.99 mol% in purity; the average grain diameter of the translucent alumina particles being at most one micrometer and the maximum grain diameter being at most two micrometer.

Fig. 1

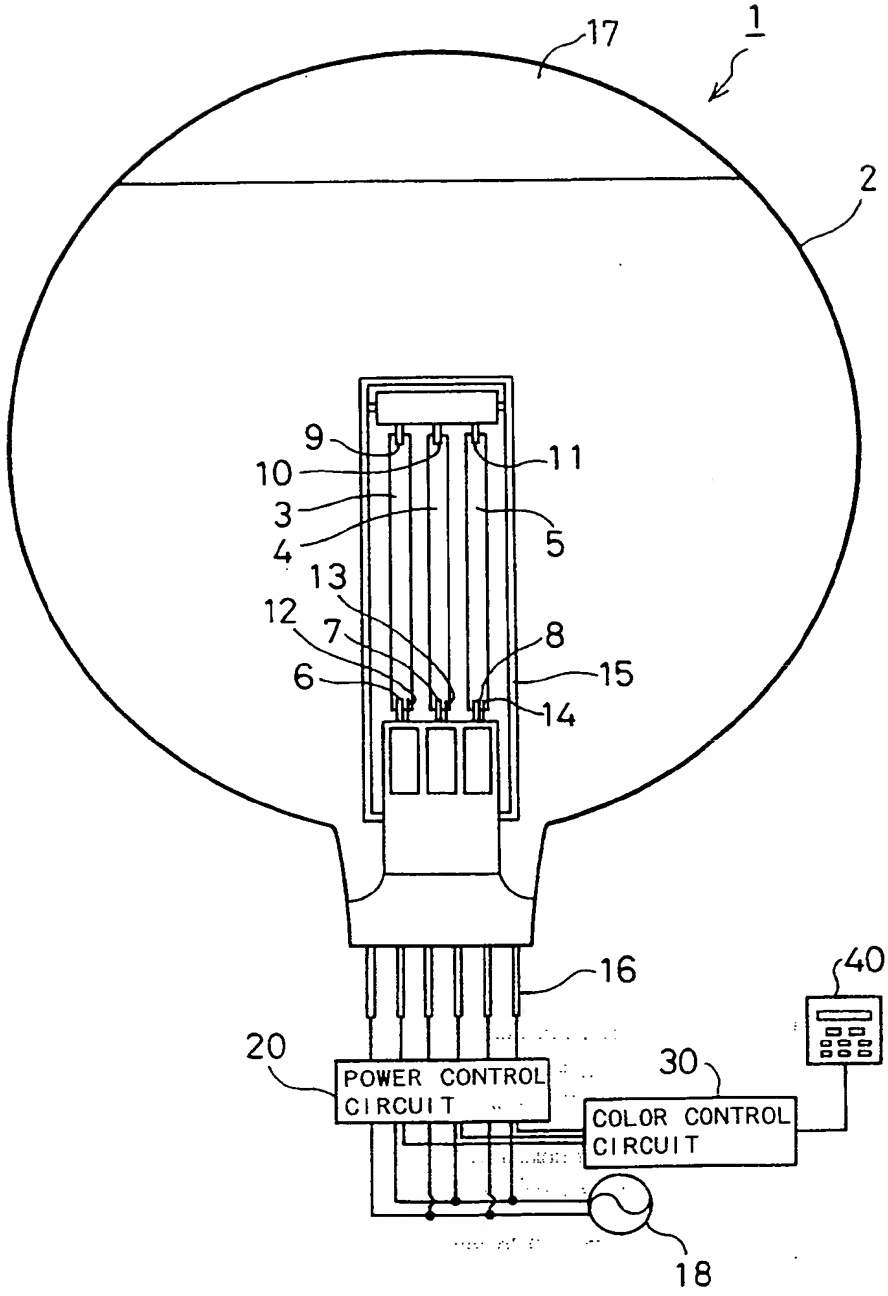


Fig. 2

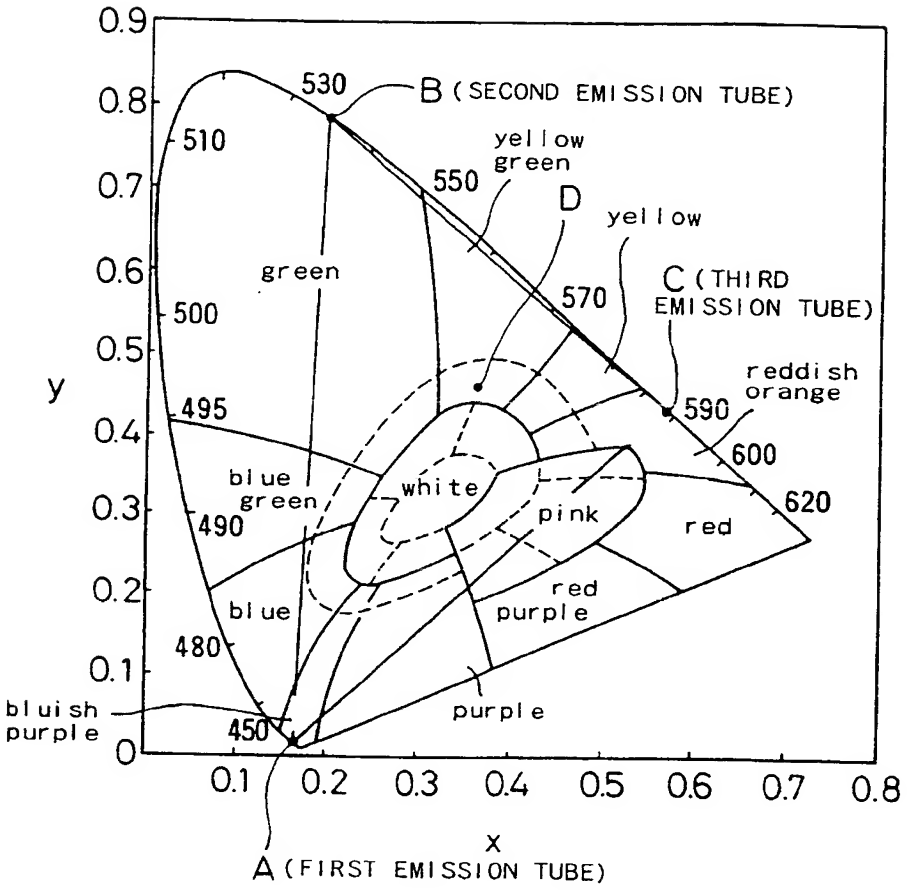


Fig. 3

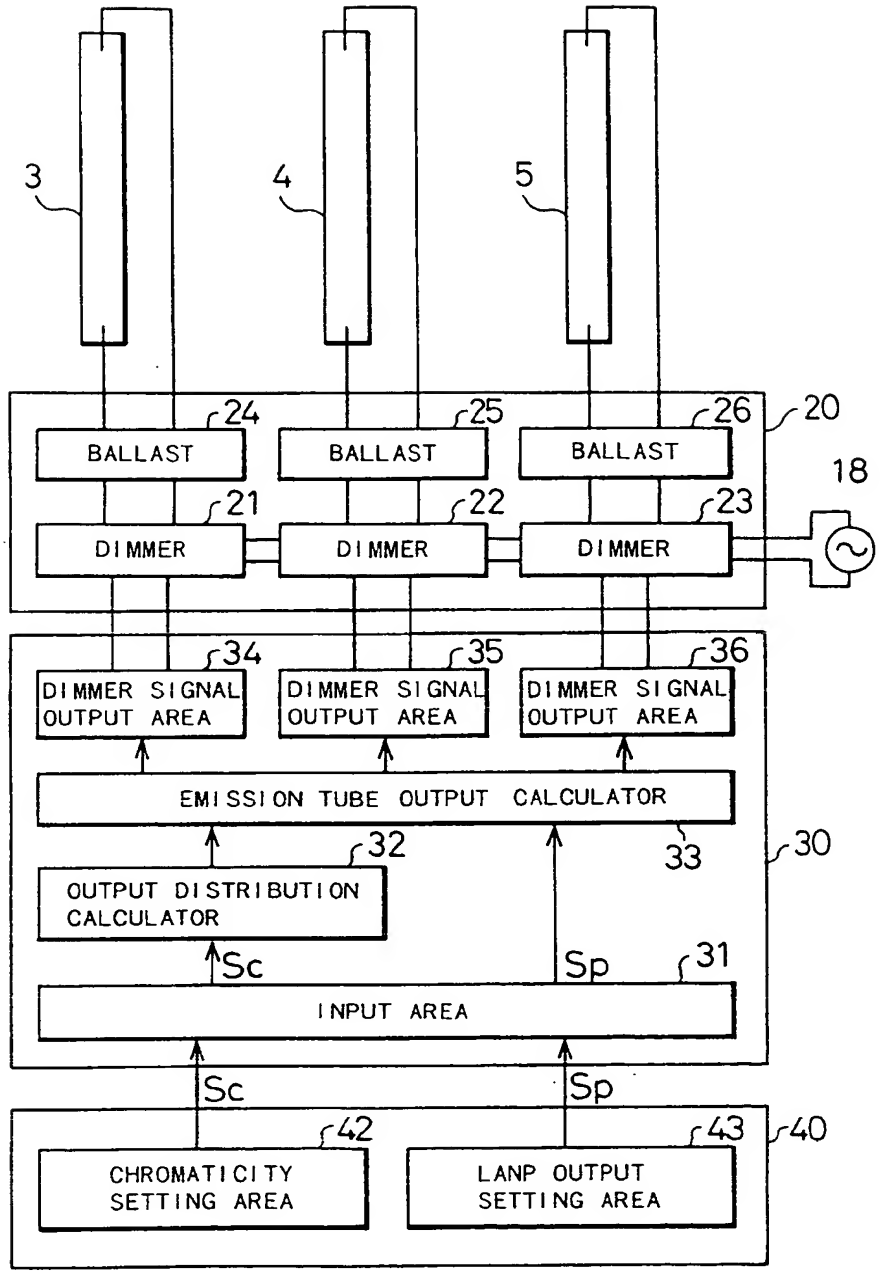


Fig. 4

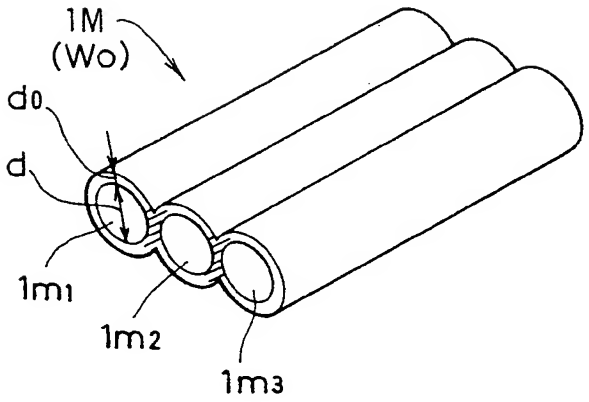


Fig. 6

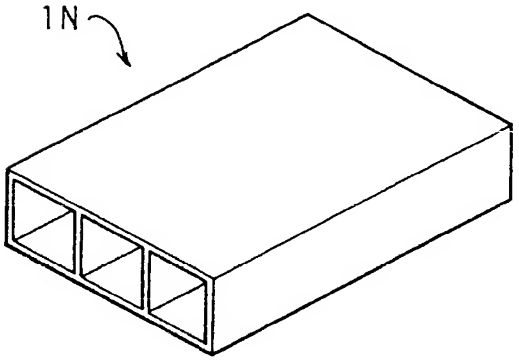


Fig. 7

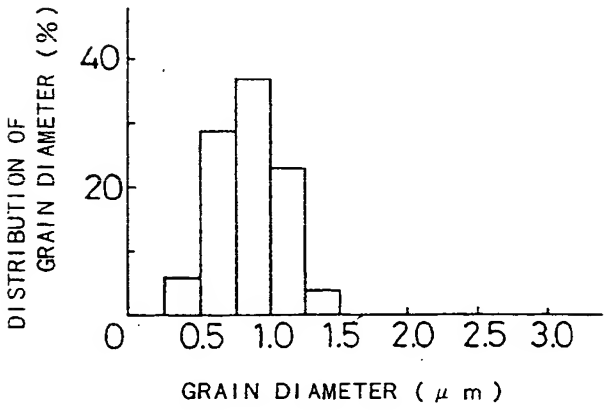


Fig. 5

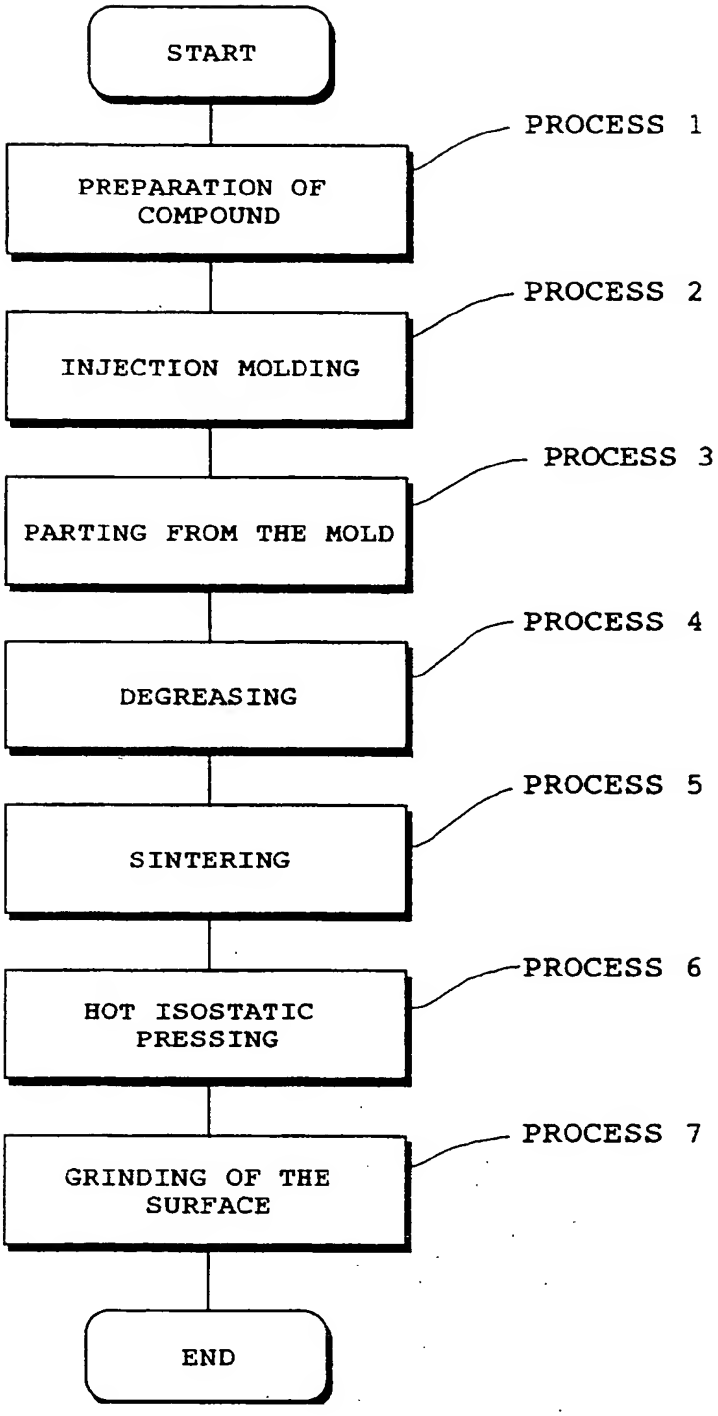


Fig. 8

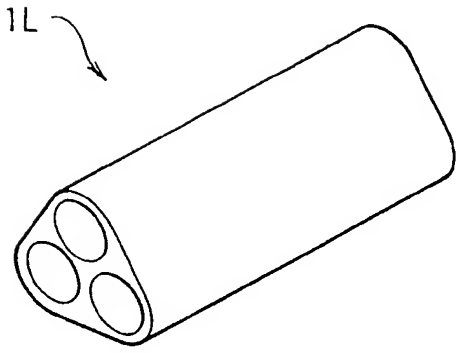


Fig. 10

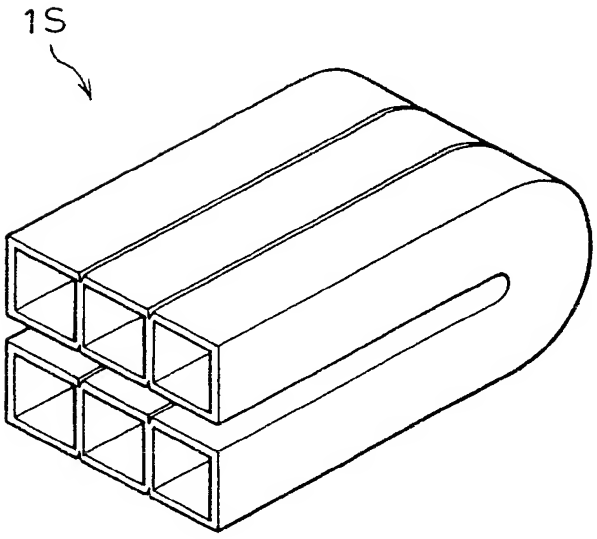


Fig. 9

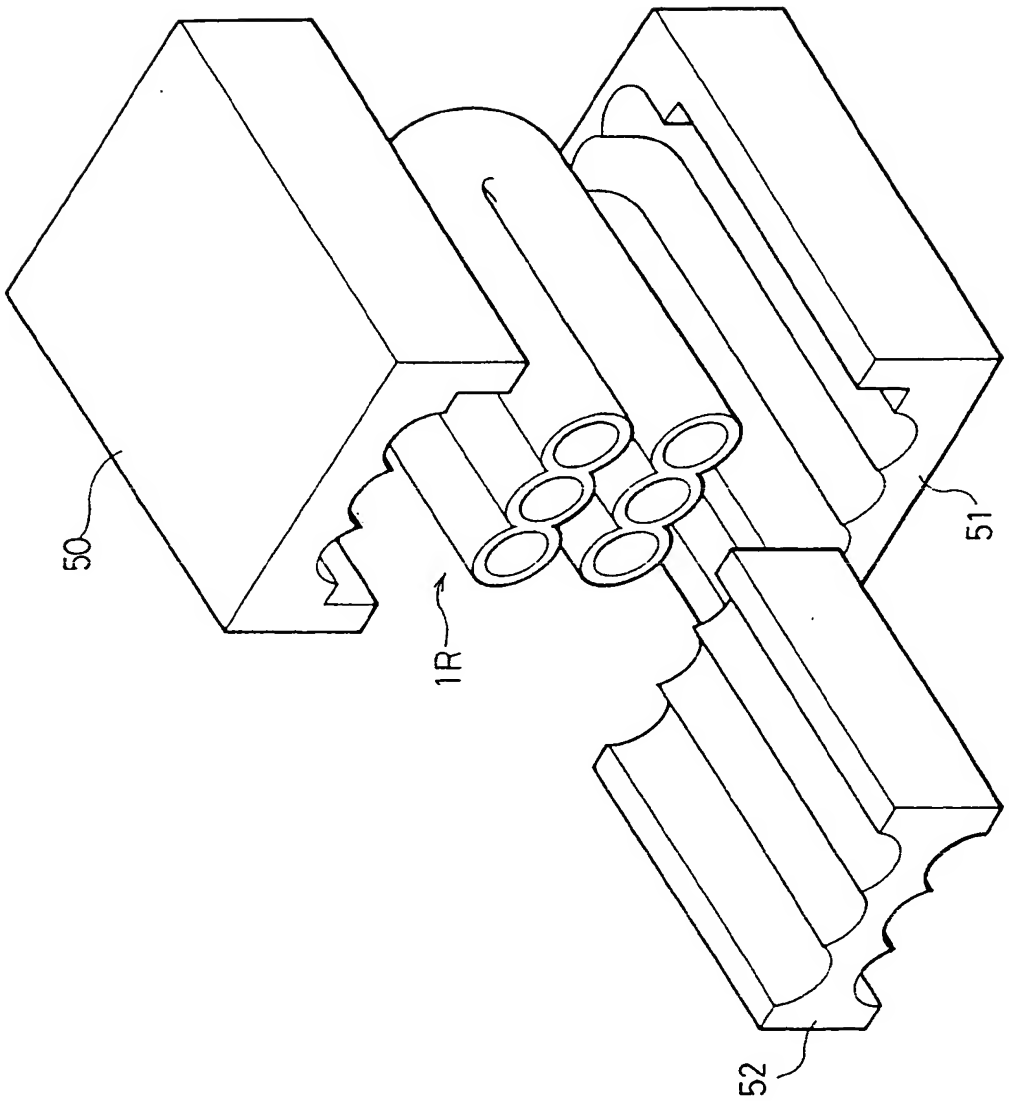


Fig. 11(a)

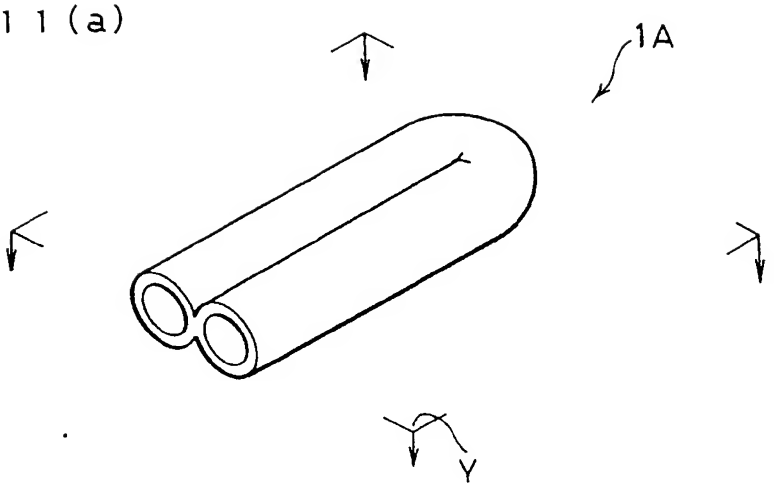


Fig. 11(b)

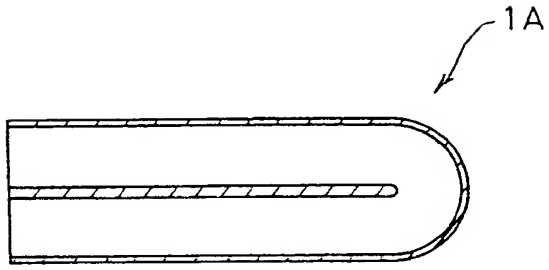


Fig. 12

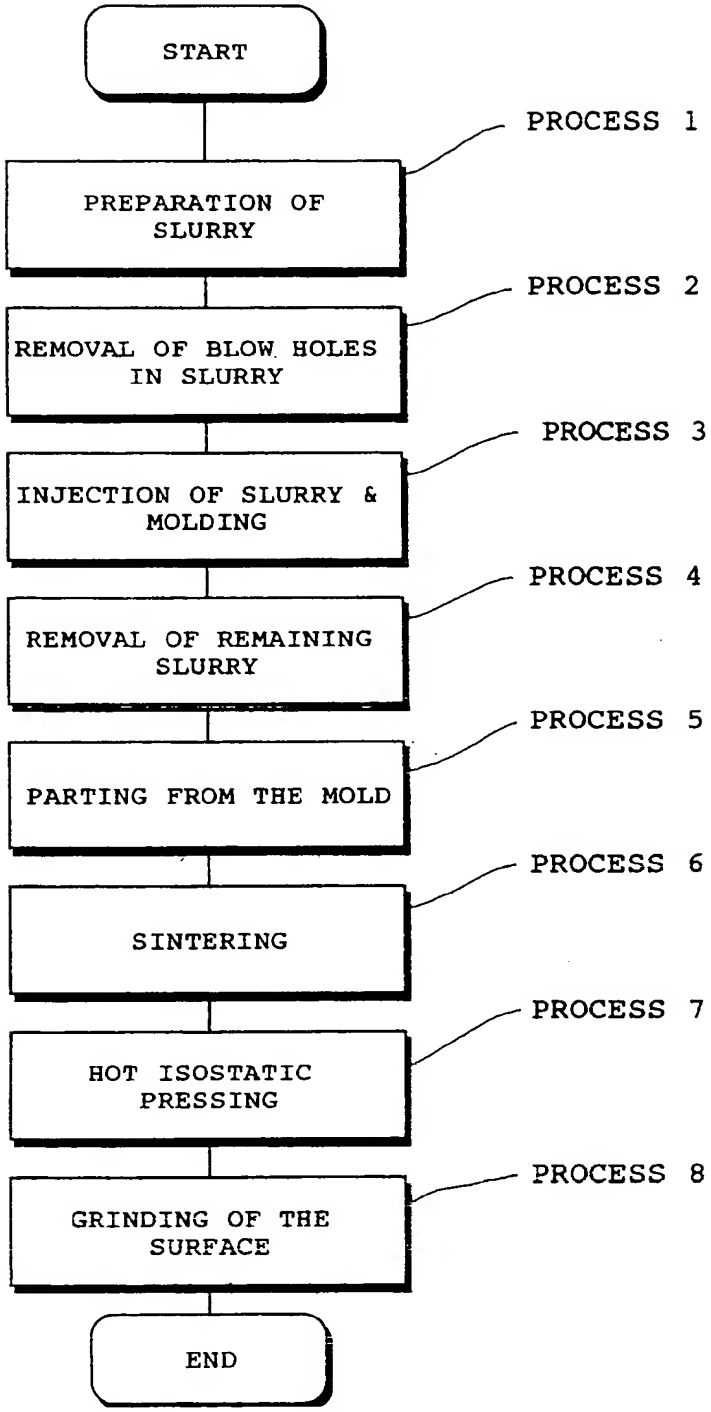


Fig. 13(a)

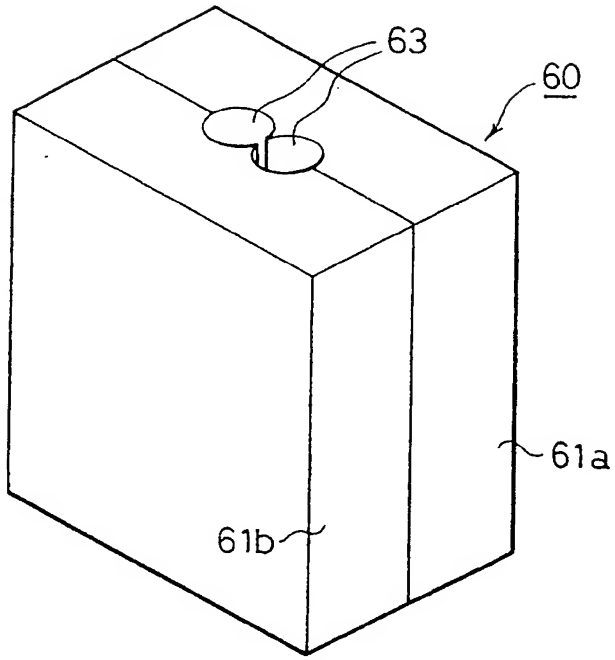


Fig. 13(b)

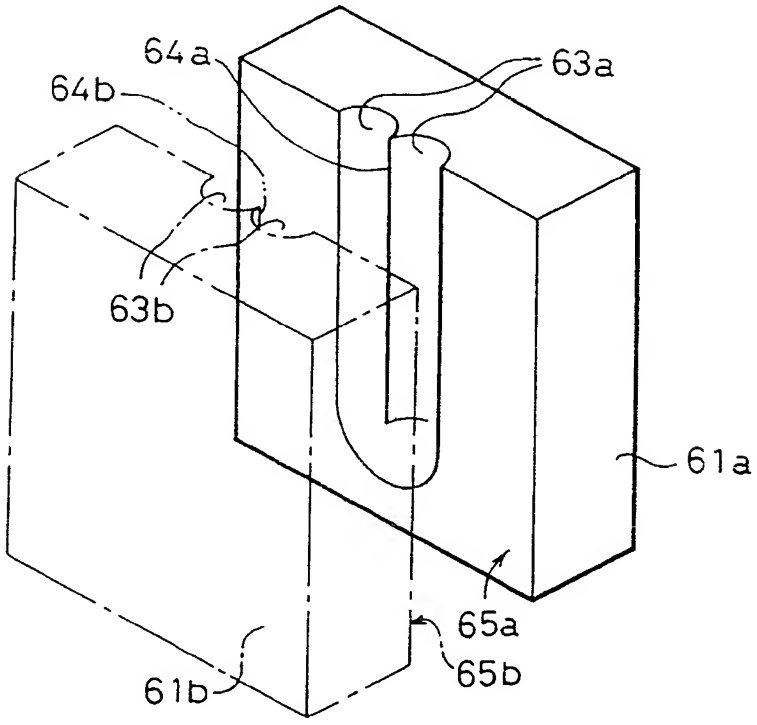


Fig. 14

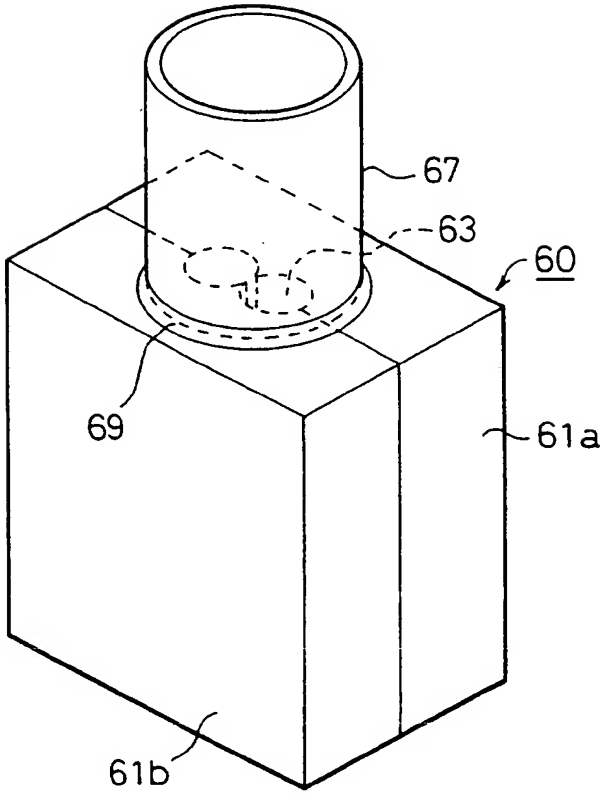
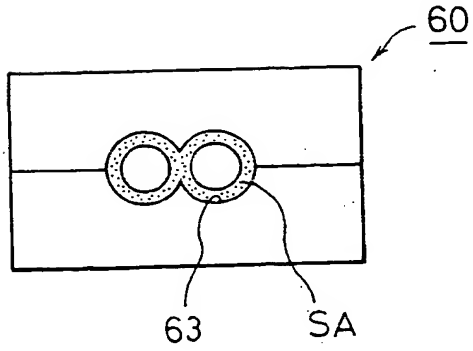


Fig. 15



INTERNATIONAL SEARCH REPORT

International Application No PCT/JP91/00962

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl[5] H01J61/94

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	H01J61/94, 61/20, 61/30, C04B35/10

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

Jitsuyo Shinan Koho 1926 - 1991
Kokai Jitsuyo Shinan Koho 1971 - 1991

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	JP, B2, 63-67315 (Toshiba Corp.), December 23, 1988 (23. 12. 88), Column 1, page 1 (Family: none)	1, 3, 5
X	JP, A, 61-22553 (Matsushita Electric Works, Ltd.), January 31, 1986 (31. 01. 86), Line 1, lower left column to line 3, lower right column, page 1 (Family: none)	1, 2, 3, 5
X	JP, A, 61-49367 (Matsushita Electric Works, Ltd.), March 11, 1986 (11. 03. 86), Lower column, page 1 (Family: none)	1, 2, 3, 5, 7
X	JP, A, 62-188158 (Matsushita Electric Works, Ltd.), August 17, 1987 (17. 08. 87), Lower column, page 1 (Family: none)	1, 2, 3, 5, 7

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
September 30, 1991 (30. 09. 91)	October 21, 1991 (21. 10. 91)
International Searching Authority	**Signature of Authorized Officer**
Japanese Patent Office	

Form PCT/ISA/210 (second sheet) (January 1985)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	JP, A, 2-132750 (Kyocera Corp.), May 22, 1990 (22. 05. 90), Lower left column, page 1 (Family: none)	8
A	JP, A, 54-154413 (Kokei Koizumi), December 5, 1979 (05. 12. 79), Lower column, page 1 (Family: none)	8
A	JP, A, 63-242964 (Nippon Glass Co., Ltd.), October 7, 1988 (07. 10. 88), Lower left column, page 1 (Family: none)	8

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers . because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers . because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers . because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	JP, A, 62-66556 (N.V. Philips' Gloeilampenfabrieken), March 26, 1987 (26. 03. 87), Upper left column, pages 1 to 2 & EP, A1, 215,524	4
Y	JP, U, 53-18876 (Iwasaki Electric Co., Ltd.), February 17, 1978 (17. 02. 78), Page 1 (Family: none)	4
A	JP, U, 58-57066 (Hitachi, Ltd.), April 18, 1983 (18. 04. 83), Page 1 (Family: none)	4

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers , because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers , because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, th[illegible]national search report covers only those claims of the international application for which fees were paid, specifically cl[illegible]

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4 ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest

☐ No protest accompanied the payment of additional search fees.